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Title: Annual Performance Testing of Tracer Gas and Tracer Aerosol Detectors for use in Radionuclide NESHAP Compliance Testing

Author(s): Fuehne, David Patrick
Lattin, Rebecca Renee

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Annual Performance Testing of Tracer Gas and Tracer Aerosol Detectors for use in Radionuclide NESHAP Compliance Testing

BACKGROUND

Los Alamos National Laboratory's (LANL's) compliance with Radionuclide NESHAP[1] regulations is managed by the Radionuclide Air Emissions Management (RAEM) team, part of LANL's Compliance Programs group (EPC-CP). One area of the Radionuclide NESHAP addresses requirements for siting a stack sample system.

Prior to commissioning a new stack sampling system, the ANSI Standard[2] for stack sampling requires that the stack sample location must meet several criteria, including uniform mixing of tracer gas (sulfur hexafluoride, SF_6) and tracer aerosol (liquid oil droplets) in the air stream. For these mix tests, tracer media are injected into the stack air stream and the resulting air concentrations are measured across the plane of the stack at the proposed sampling location. The coefficient of variation of the media concentration must be under 20% when evaluated over the central 2/3 area of the stack or duct. The instruments which measure these air concentrations must be tested prior to the stack tests in order to ensure their linear response to varying air concentrations of either tracer gas or tracer aerosol.

This memo documents the most recent performance tests of the sulfur hexafluoride detectors for use in stack gas mixing tests, as well as the functional trending test on a pair of optical particle counters, comparing results from a non-calibrated instrument to a calibrated instrument.

The instruments used in tracer gas and aerosol mix testing cannot be locally calibrated by the LANL Standards and Calibration Laboratory, so they would normally be sent off-site for factory calibration by the vendor. However, the vendor for aerosol particle counters cannot perform a factory calibration on instruments after they have been used in hazardous settings, e.g., within a radiological facility with potential airborne contamination. Therefore, a factory-calibrated instrument and a "working" unit used in radiological facilities are exposed to the same clean air stream, with varying concentrations of aerosol, and the relationship between the readings on the two instruments is evaluated.

Similarly, the vendor supplying the SF_6 detectors does not provide factory calibration. Therefore, these detectors are exposed to an air stream with uniformly varying

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[1] The term Radionuclide NESHAP or Rad-NESHAP refers to the National Emissions Standards for Hazardous Air Pollutants, regarding air emissions of radionuclides. This standard is put forth in Title 40 of the Code of Federal Regulations, Part 61, Subpart H, "National Emission Standards for Emissions of Radionuclides Other Than Radon from Department of Energy Facilities."

[2] American National Standards Institute ANSI N13.1-1999, "Sampling and Monitoring Releases of Airborne Radioactive Substances form the Stacks and Ducts of Nuclear Facilities." Incorporated by reference into 40 CFR 61, Subpart H, above.

concentrations, and the linearity of the response is evaluated. The performance tests described in this document are intended to demonstrate the reliable performance of the test instruments for the specific tests used in stack flow characterization.

METHODS

Sulfur Hexafluoride Detector Tests

Sulfur hexafluoride (SF_6) is used as the tracer gas to evaluate uniformity in gas mixing within the stack. The instrument of choice for this type of measurement is the InfraRan gas analyzer, by Wilkes Instruments. This instrument's ideal range is 0-3 parts per million (ppm), with a calibrated range up to 5 ppm. The instrument is portable, has a fast response, and can log data for later off-line evaluation. While an absolute calibration is not needed, the unit must accurately measure variations in SF_6 concentration in order to evaluate gas mixing across the stack profile. A linear response between air concentration and instrument response is desired to allow easy comparison between measurement points. Two instruments were tested, dubbed "Detector 91" and "Detector 92" based on their LANL property numbers.

In prior years[3,4], the SF_6 response was measured by injecting known amounts of SF_6 into the test isolation chamber maintained by the Radiation Protection Services group at LANL. In this case, gas analyzers were continuously measuring SF_6 concentration inside the chamber as a series of injections are made. However, due to COVID-19 issues, the RP-SVS chamber was not available this year. Instead, RAEM staff performed the test using the team's wind tunnel at Technical Area 35, injecting SF_6 directly from a pressure bottle into the wind tunnel duct and varying the duct speed and gas injection pressure to determine linearity of response.

We performed a series of tests on January 8, 2021. The first test was simply designed to evaluate trending and response to varying levels of SF_6. Gas was injected into the duct, and the injection rate was adjusted until a stable reading was achieved. The concentration in the duct was then changed by varying the injection rate or adjusting the fan flow rate; a higher flow decreases the concentration and lower flow will increase the duct concentration. While this test showed excellent trending and response, there was no way to establish linearity between injection rate and instrument response. The trend plot from this first test appears in Figure 1.

A second test was performed, using the fine control of the regulator to provide a measureable injection level, starting at 2 psi. The fan stayed steady at the 80% power level. The injection pressure was then increased to provide a quantifiable level of change. While we are not attempting to calculate an absolute flow rate based on the pressure level, the pressure reading will allow a numerical evaluation of the changing rate of increase. At each pressure level, a series of measurements were made for each

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[3] LA-UR-08-07829, "SF6 Detector Performance Test Results," Transmitted in memo ENV-EAQ:08-267, Rebecca Lattin and David Fuehne, November 12, 2008.

[4] LA-UR-17-25161, "Performance Testing of Tracer Gas and Tracer Aerosol Detectors for use in Radionuclide NESHAP Compliance Testing," David Fuehne and Rebecca Lattin, June 28, 2017.

detector. We used the trend line feature in Excel to determine a curve fit, and the "adjusted R-square" was used to estimate linearity of the curve. The results of this test appear in Figure 2.

The third test was a repeat of the second test, but with the fan speed maintained at 50% power. Time constraints limited the number of test runs for this final test. Results of the third test appear in Figure 3. Complete data from these three tests appear in Attachment 1.

It should be noted that the InfraRan instrument reads out in parts per million (PPM), but this value is not corrected for ambient air pressure or temperature. This corresponds to the Permissible Exposure Limits (PEL) established by the Occupational Safety and Health Administration (OSHA), which are "fixed and not subject to corrections for temperature and pressure." [NIOSH Manual for Analytical Methods, Appendix B]. The InfraRan effectively measures the number of molecules of the gas of interest then converts that to a ppm value assuming standard temperature and pressure conditions. [Electronic communication with Wilkes Instruments personnel, Nov 5 2008.]

Aerosol Detector Tests

The aerosol detector testing is more complicated, since one cannot inject controlled amounts of 10-micron particles into an isolation chamber. Instead, a calibrated instrument is used to evaluate the response of the field unit used in radiological facility testing. The non-calibrated field unit and the calibrated unit are set up with nearly identical extraction systems and collocated in the air stream at the EPC Division test duct at TA-35-0034. Using a cylinder of compressed air and a fuel oil nozzle, a liquid oil aerosol is generated from vegetable oil and injected into the duct. Varying aerosol concentrations are obtained by varying the wind tunnel duct fan speed. One can also adjust aerosol concentrations by varying compressor pressures or injector nozzle orientation, but the fan speed is the easiest to control and easiest method to achieve dramatically different aerosol concentration results.

The instruments used for measuring particulates in this situation are AeroTrak portable particle counters made by TSI Inc. These instruments can measure particles from 0.3 μm in size up to 25 μm in size. EPC-CP uses the 5 μm and the 10 μm bins for measurements as these are the typical particle size seen in stack sampling. These detectors have a quick response, are portable, and can log data as needed. An absolute calibration is not needed to evaluate particulate mixing within a stack, just a relative comparison between points. Therefore, the trends of the non-calibrated detector was compared to the trends of the calibrated detector within the same air stream to ensure that the non-calibrated unit accurately measures the variability of concentration of particulates.

The AeroTrak instruments were set up to take one minute counts of particulates in the air stream when the "count" button was pushed. Prior to testing, the instruments were operated with a HEPA filter in place to verify zero. Background measurements were then taken to determine the baseline in the duct air stream. Next, vegetable oil aerosol

was generated and injected into the wind tunnel duct. The fan speed was varied in order to vary the concentration of oil particles reaching the detectors.

On January 8, 2021, EPC-CP took a series of measurements at varying fan speeds. Both instruments were zeroed for a series of measurements. Then a series of background measurements were taken. With the aerosol entering the air stream, four measurements were taken at each of five different fan speeds: 35%, 70%, 25%, 80%, and 50%. Finally, more background measurements were taken with the aerosol removed from the air stream, and additional measurements were taken with the zero filters installed on the particle counters.

All data collected from the tests were entered into an Excel spreadsheet to graph the trends of both detectors. In the images above, one can see that there are more bends and horizontal runs in the transfer tubing for the calibrated detector 02 (left) than for the field detector 03 (right). As expected, this resulted in lower readings for the calibrated unit detector 02.

The ratio of the field instrument counts to the calibrated instrument counts was calculated at each point; the coefficient of variance (COV) was determined for this ratio. The field unit is considered usable if the ratio between the field unit and calibrated unit remains fairly constant. Complete results from these tests can be found in Attachment 2.

EQUIPMENT

Sulfur Hexafluoride Detector Tests

- Wilks InfraRan Specific Vapor Analyzer, calibrated to sulfur hexafluoride
    - Model # 405-2000-1017; Serial Number 147; LANL Property # 1114591 referred to as “Detector 91”

    - Model # 405-2000-1017; Serial Number 148; LANL Property # 11145**92** referred to as "Detector 92"
- Pressure cylinder of commercial grade sulfur hexafluoride
- Pressure regulator and manifold, LANL Pressure System #3653
- Various transfer tubing
- Extraction tubing affixed to bent metal; ensures both detectors measure the same point in the air duct.

Aerosol Detector Tests

- TSI AeroTrak Portable Particle Counter
    - Model # APC 9310-01N; Serial Number 9310093602; referred to as "Detector 02;"
      LANL Property # 1212264;
      Factory calibrated in January 2020; expires 1/27/2021.
    - Model # APC 9310-01N; Serial Number 9310093603; Referred to as "Detector 03"
      LANL Property # 1212265 (non-calibrated)
- Pressure cylinder of compressed air
- Pressure regulator and manifold, LANL Pressure System #3653
- Vegetable oil
- Various transfer tubing

Aerosol Sample Extraction Manifold

- Two bent copper tubes and vinyl tubing
- Pipe manifold and mount to keep tubes stationary throughout test

EVALUATION TEAM

Tests performed by: David Fuehne, EPC-CP (due to COVID-19 limitations, it is discouraged to have multiple people in common space).
Data analysis by: David Fuehne & Rebecca Lattin, EPC-CP

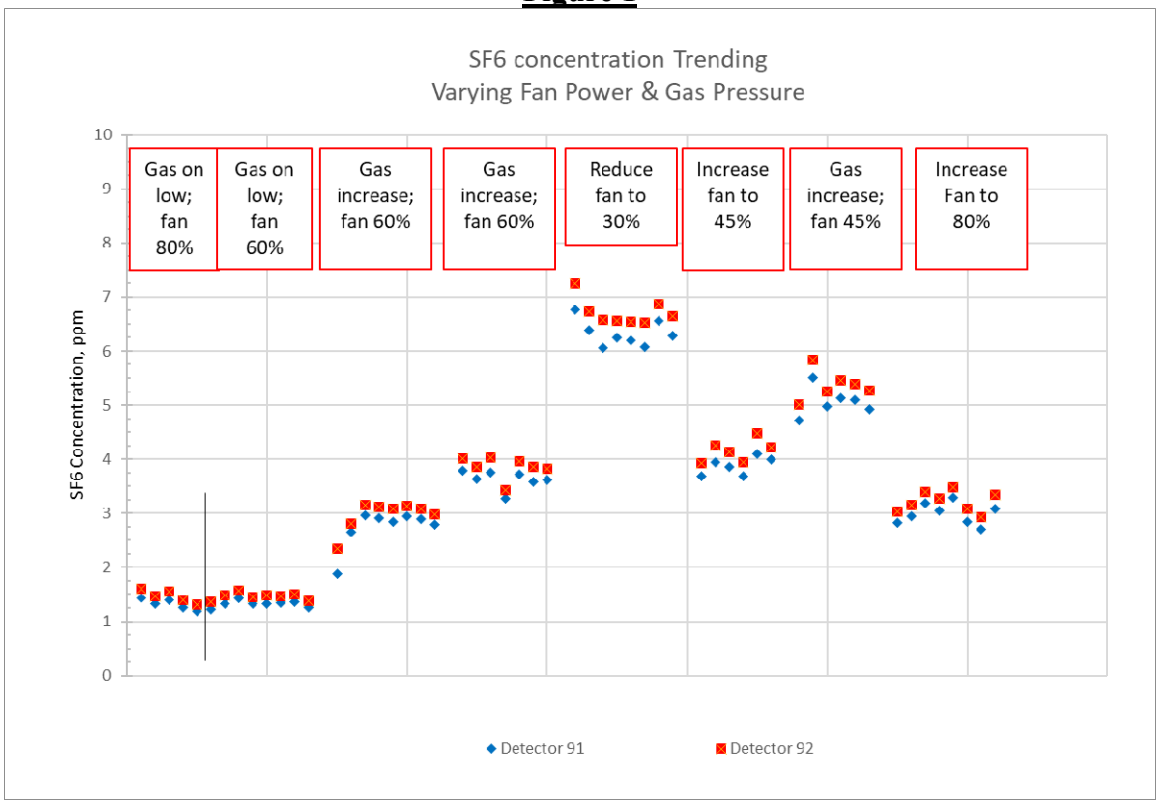
DATA

Sulfur Hexafluoride Detector Tests

The data logs from all tests for both EPC-CP instruments appear in Attachment 3. We did not attempt to log data with the detectors or electronically transfer results. Therefore, the only data available for these tests were from the hand-written records. The plots and data are broken up by detector and then by test. Data entry was verified by an independent person.

The first test evaluated the detector response to changing levels of tracer gas in the duct. While this test showed excellent trending and response, there was no way to establish linearity between injection rate and instrument response. The trend plot from this first test appears in Figure 1.

Figure 1



The second test used the regulator's fine control to allow a numerical relationship between the injection rate and detector response to be developed. We did not attempt to calculate the actual rate of injection, but the injection pressure does provide a direct relationship with the level at which the gas is entering the duct. The trend line feature in Excel can determine a curve fit between the detector response and injection pressure, and the "R-square" value will estimate the linearity of the curve. The results of this test, using all data points, appear in Figure 2. We then calculated an average concentration at each setting and plotted trend lines based on these average values. The results appear in Figure 2a.

Figure 2

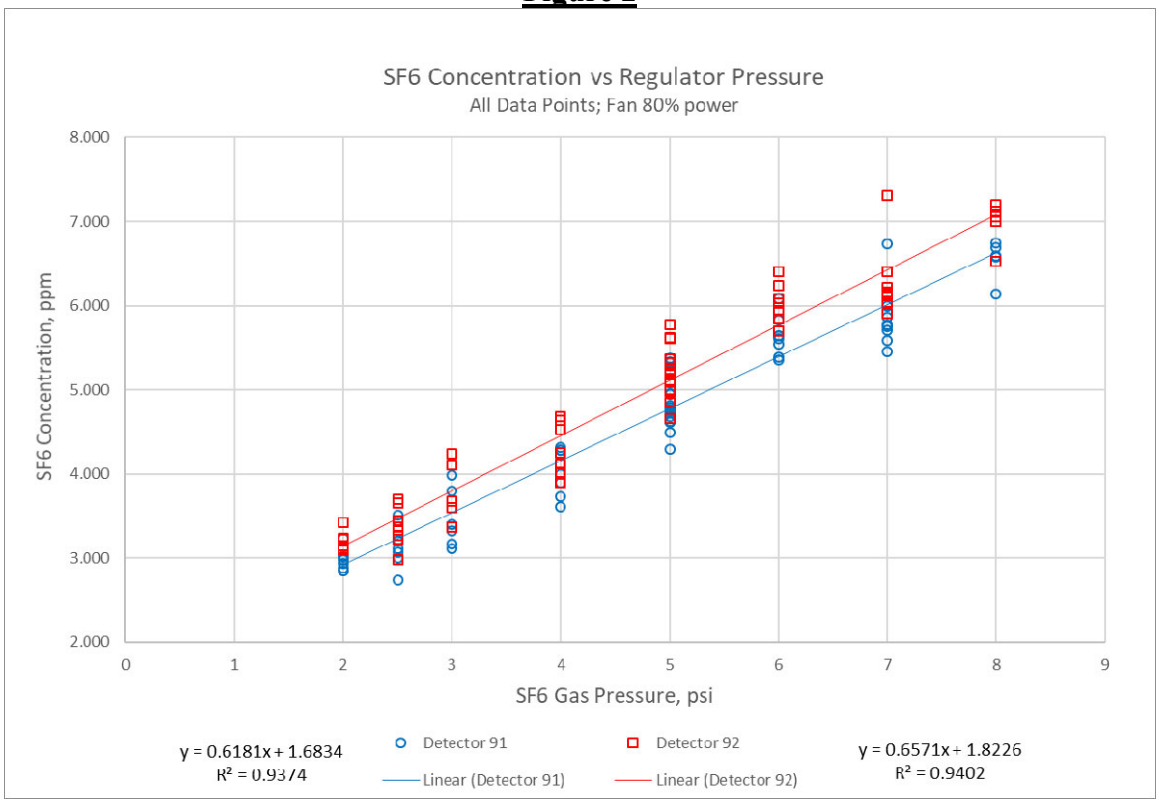
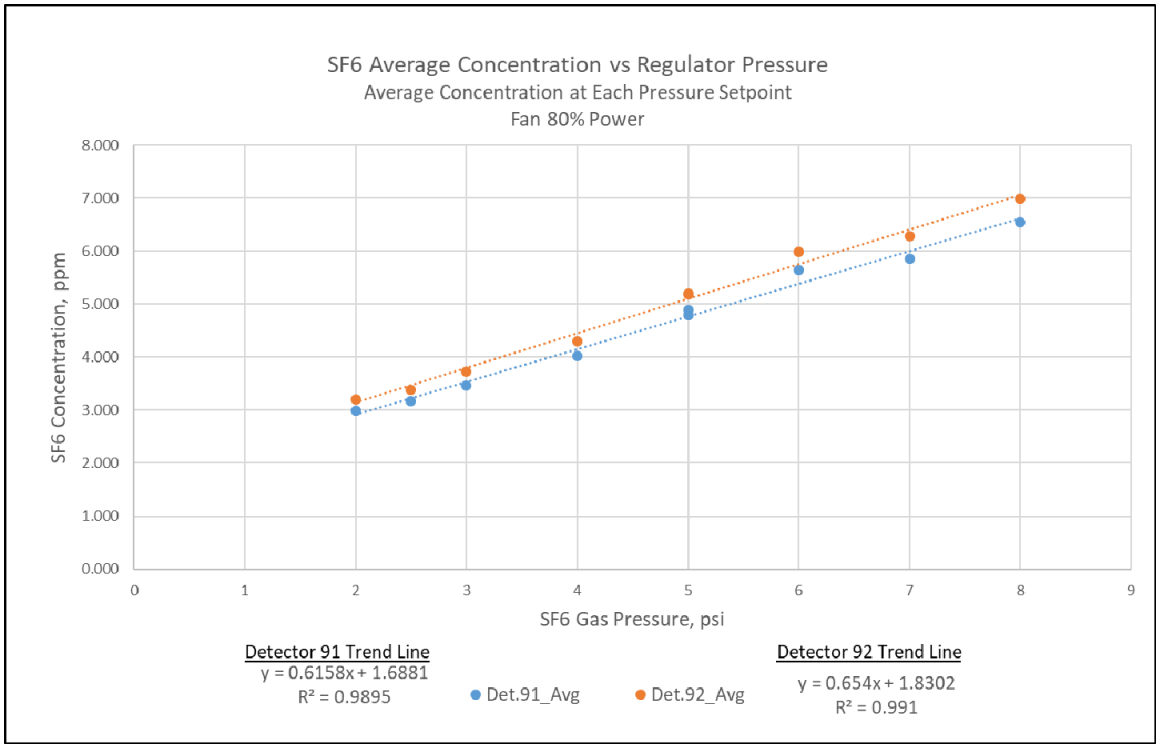


Figure 2a



The third test was a repeat of the second test but at a lower fan speed. Time constraints limited the number of test runs for this final test. Results of the third test appear in Figure 3, with all data points included in the analysis. Again, the average values at each injection pressure set point were calculated. The plot and trend line from the average values appears as Figure 3a.

Figure 3

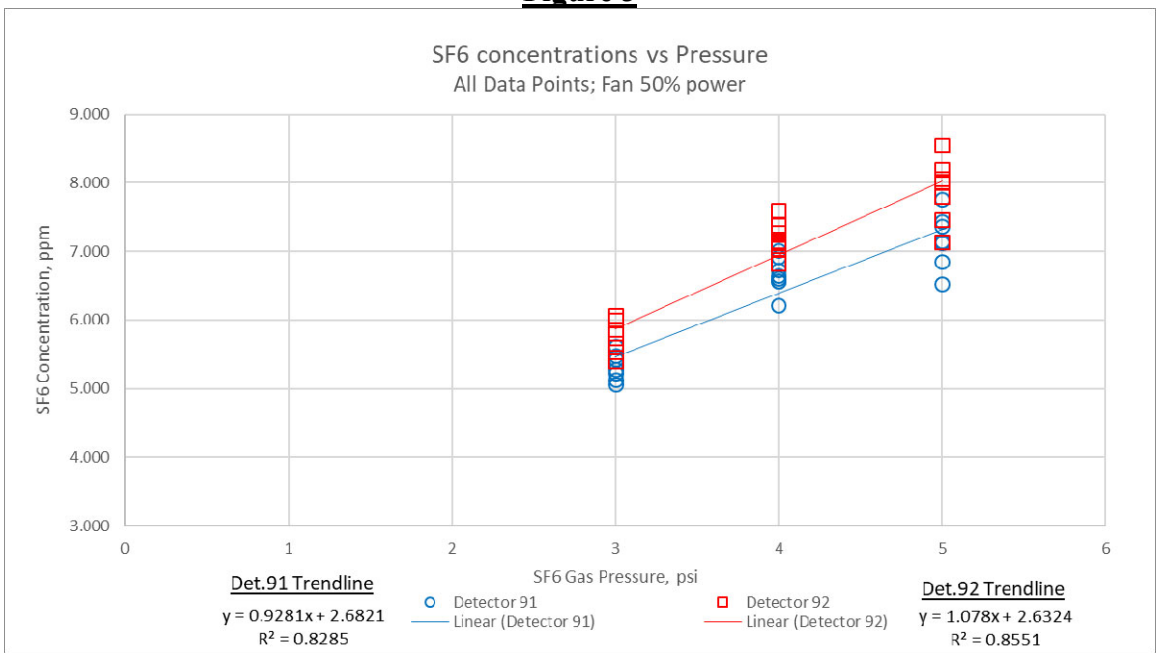
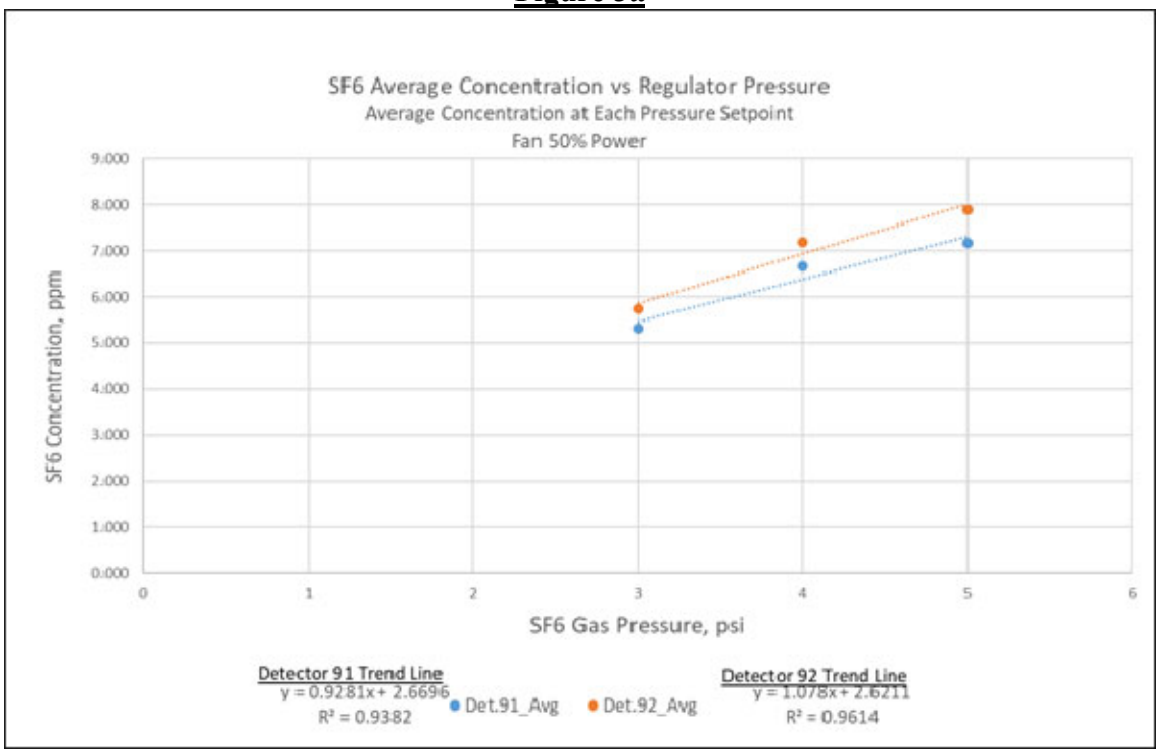


Figure 3a



Aerosol Detector Tests

Attachment 2 shows the hand-logged data for both aerosol detectors that were entered into an Excel spreadsheet. Both AeroTrak detectors measure 5 µm and 10 µm particles simultaneously. Since we were looking to see if our non-calibrated unit (Detector 03) trends with our calibrated unit (Detector 02), we recorded and analyzed the data for the two particle sizes separately. Data entry was verified by an independent person. Attachment 2 also shows the graphs of the data (Figures 4 and 5) to show the detectors' trends as the fan speeds, and thus aerosol concentrations, changed.

For each bin (5 micrometer and 10 micrometer), the average ratio between detector 02 and detector 03 measurements was calculated as well as the standard deviation and the coefficient of variance. Page one of Attachment 2 shows the data and the calculated average ratio, standard deviation, and COV. Figure 4 shows how each detector trended during the tests over time for the 5 micrometer bin. Figure 5 shows the same information except for the 10 micrometer bin.

Figure 4

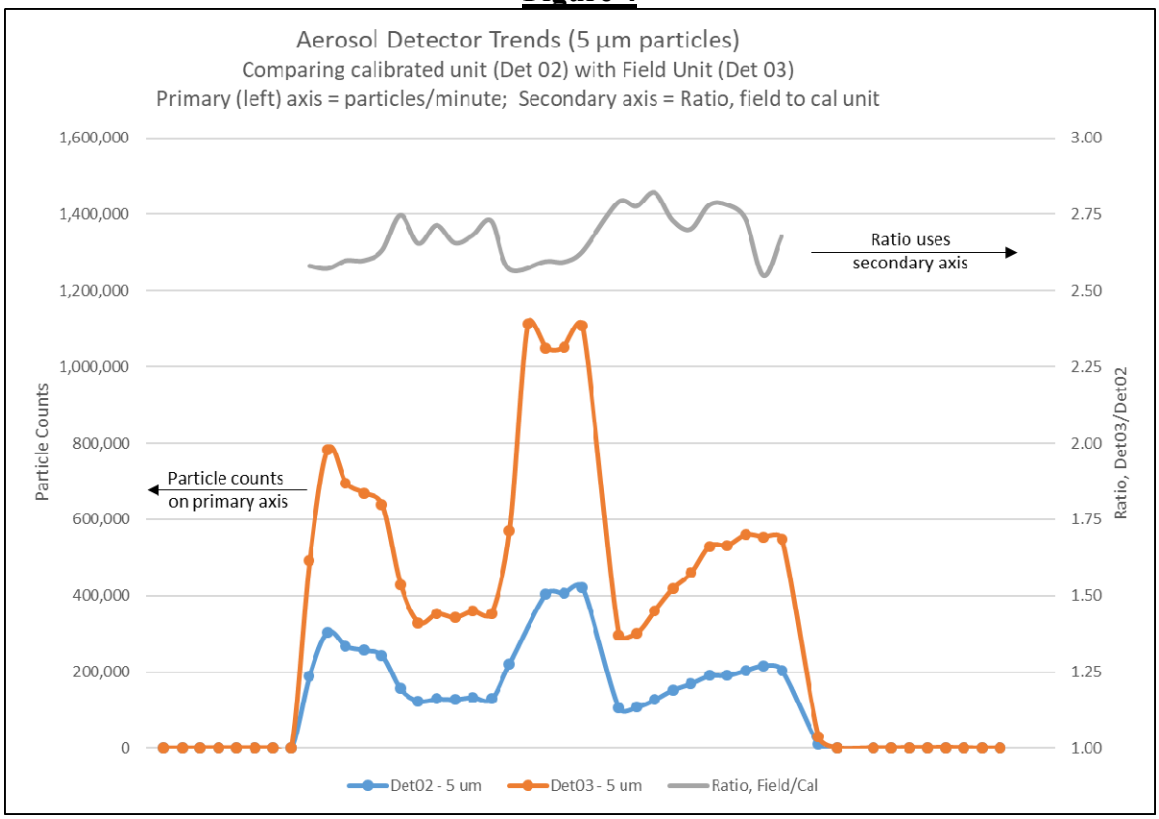
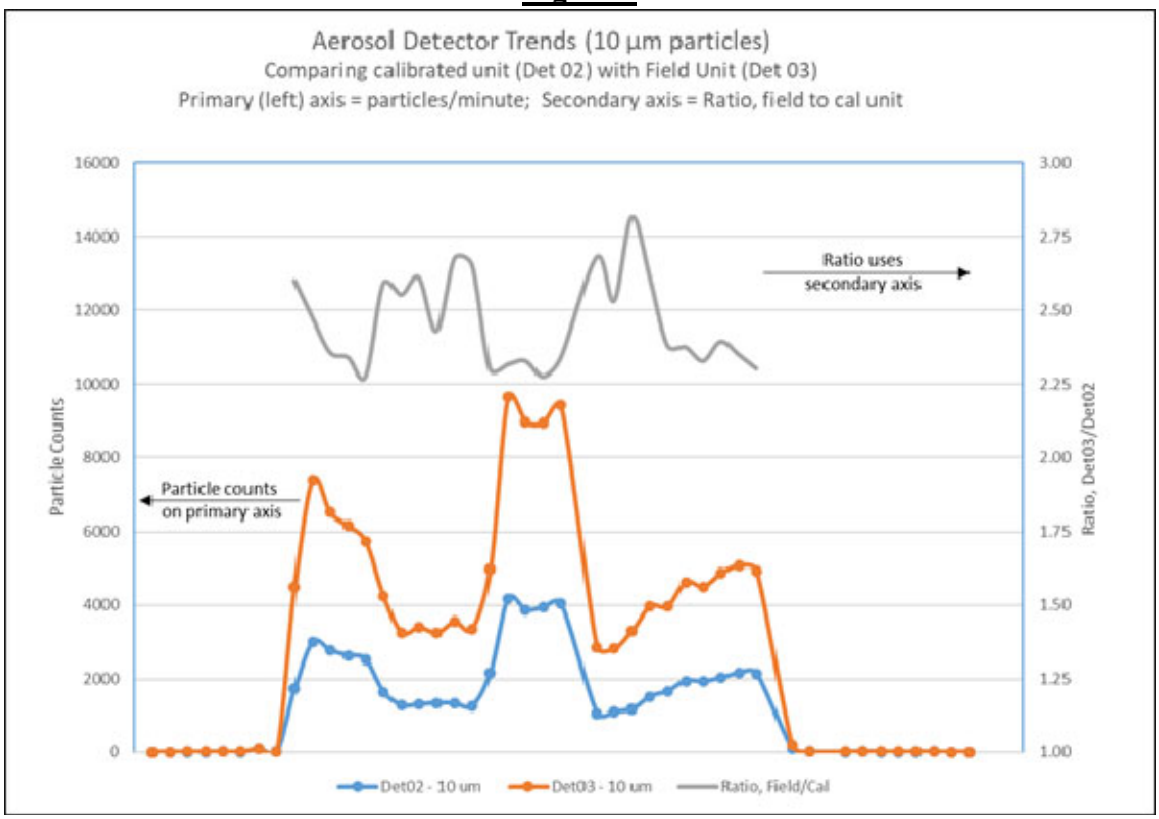


Figure 5



RESULTS & CONCLUSIONS

Sulfur Hexafluoride Detector Tests

Table 1 below shows the linearity of response evaluation for the different SF_6 tracer gas test. Linearity is determined using the "R-square" value of the trend line.

Table 1 Sulfur Hexafluoride Detector Test Results	
Test	**Linear Response (R-squared)**
SF_6: Fan 80%; all data; Detector 91	93.74%
SF_6: Fan 80%; all data; Detector 92	94.02%
SF_6: Fan 80%; averaged data; Detector 91	98.95%
SF_6: Fan 80%; averaged data; Detector 92	99.10%
SF_6: Fan 50%; all data; Detector 91	82.85%
SF_6: Fan 50%; all data; Detector 92	85.51%
SF_6: Fan 50%; averaged data; Detector 91	93.82%
SF_6: Fan 50%; averaged data; Detector 92	96.14%

Focusing on the "80% fan" test which had a more comprehensive data set, results were excellent – over 90% at all data points and over 98% when comparing the average result at each point. For each test, both detectors showed a linear response to varying levels of sulfur hexafluoride and all detectors are suitable for use in Rad-NESHAP compliance measurements.

Aerosol Detector Tests

Table 2 shows the summary results of comparing the response of the two detectors. The goal is to show the field detector responds in a manner similar to the calibrated detector.

Table 2 – Aerosol Detector Test Results Ratio of field unit (03) to calibrated unit (02)		
5 micron bin	Average Ratio	2.676
	Standard Deviation	0.08
	Coefficient of Variation	3.0%
10 micron bin	Average Ratio	2.457
	Standard Deviation	0.15
	Coefficient of Variation	6.3%

Visual inspection of Figures 4 and 5 show that the two detectors trend together; the field unit trends similarly to the calibrated unit. Quantitatively, the ratio between the readings at different concentrations are quite close; the 5-micron bin ratio showed a 3% COV while the 10-micron bin showed a less than 10% COV. The COV for readings is based on times when aerosol injections were taking place, as opposed to using ambient background counts. Also, it is expected that the 10-micron bin would vary more widely, since larger diameter particles are more subject to losses due to extraction system design and flow rate variability. A COV of less than 10% indicates that the field detector varies similarly to the factory-calibrated unit, and the field unit is therefore suitable for the sample site testing to meet Rad-NESHAP compliance.

Attachment 1

Sulfur Hexafluoride Detector Tests – Data, Calculations & Graphs

Performance Test of Tracer Gas Detectors

Jan 8 2021

Detector 91
Detector 92

Goal: show Detectors trend uniformly with changing levels of tracer gas (sulfur hexafluoride).

Stack tests measure variability of tracer media across cross-section of duct.

Time	Fan Status	SF6 gas	Detector 91	Detector 92
14:56:00	fan off	none; background	-0.025	-0.044
15:57:00	fan off	none; background	-0.025	-0.042
	fan off	none; background	-0.027	-0.041
	fan off	none; background	-0.026	-0.040
	fan off	none; background	-0.027	-0.040
	50% power	none; background	-0.025	-0.037
	50% power	none; background	-0.024	-0.039
	50% power	none; background	-0.030	-0.040
	50% power	none; background	-0.030	-0.042
	50% power	gas on	saturated	saturated
	80% power	gas turned off	rezero	rezero
	80% power	none; background	-0.074	0.017
	80% power	none; background	-0.078	0.010
15:17:00	80% power	gas on trace	1.426	1.600
15:17:30	80% power	gas on trace	1.323	1.464
15:18:00	80% power	gas on trace	1.403	1.550
15:18:30	80% power	gas on trace	1.266	1.397
15:19:00	80% power	gas on trace	1.181	1.307
15:19:30	80% power; drop to 60%	gas on trace	1.221	1.358
15:20:00	60% power	gas on trace	1.332	1.477
15:20:30	60% power	gas on trace	1.436	1.570
15:21:00	60% power	gas on trace	1.322	1.446
15:21:30	60% power	gas on trace	1.325	1.474
15:22:00	60% power	gas on trace	1.336	1.470
15:22:30	60% power	gas on trace	1.368	1.501
15:23:00	60% power	gas on trace	1.253	1.377
	60% power	bump up gas		
15:24:00	60% power	2x original	1.882	2.334
15:24:30	60% power	2x original	2.650	2.815
15:25:00	60% power	2x original	2.956	3.151
15:25:30	60% power	2x original	2.902	3.112
15:26:00	60% power	2x original	2.850	3.086
15:26:30	60% power	2x original	2.945	3.133

Average for each setting

#Bumps above zero	Det 91	Det 92
1	1.320	1.464
	x	x
	x	x
	x	x
	x	x
	txn	txn
1	1.339	1.474
	x	x
	x	x
	x	x
	x	x
	x	x
	x	x
	txn	txn
	txn	txn
2	2.854	3.051
	x	x
	x	x
	x	x
	x	x

Performance Test of Tracer Gas Detectors

Jan 8 2021

Detector 91
Detector 92

Goal: show Detectors trend uniformly with changing levels of tracer gas (sulfur hexafluoride).

Stack tests measure variability of tracer media across cross-section of duct.

Time	Fan Status	SF6 gas	Detector 91	Detector 92			
15:27:00	60% power	2x original	2.893	3.084		x	x
15:27:30	60% power	2x original	2.783	2.976		x	x
15:28:00	60% power	bump up gas				txn	txn
15:29:00	60% power	3x original	3.790	4.014	3	3.623	3.848
15:29:30	60% power	3x original	3.628	3.862		x	x
15:30:00	60% power	3x original	3.750	4.022		x	x
15:30:30	60% power	3x original	3.277	3.419		x	x
15:31:00	60% power	3x original	3.718	3.952		x	x
15:31:30	60% power	3x original	3.587	3.850		x	x
15:32:00	60% power	3x original	3.612	3.817		x	x
15:32:30	reduce fan speed	3x original				txn	txn
15:33:00	30% power	3x original	6.771	7.255		txn	txn
15:33:30	30% power	3x original	6.389	6.725	4	6.258	6.632
15:34:00	30% power	3x original	6.058	6.577		x	x
15:34:30	30% power	3x original	6.253	6.552		x	x
15:35:00	30% power	3x original	6.190	6.541		x	x
15:35:30	30% power	3x original	6.081	6.517		x	x
15:36:00	30% power	3x original	6.562	6.867		x	x
15:36:30	30% power	3x original	6.276	6.645		x	x
	increase fan speed	3x original				txn	txn
15:38:00	45% power	3x original	3.681	3.926		txn	txn
15:38:30	45% power	3x original	3.948	4.259	3	3.919	4.205
15:39:00	45% power	3x original	3.863	4.135		x	x
15:39:30	45% power	3x original	3.692	3.945		x	x
15:40:00	45% power	3x original	4.104	4.473		x	x
15:40:30	45% power	3x original	3.988	4.214		x	x
15:41:00	45% power	bump up gas				txn	txn
15:41:30	45% power	4x original	4.721	5.013		txn	txn
15:42:00	45% power	4x original	5.511	5.833	4	5.128	5.441
15:42:30	45% power	4x original	4.979	5.253		x	x
15:43:00	45% power	4x original	5.125	5.454		x	x
15:43:30	45% power	4x original	5.094	5.393		x	x
15:44:00	45% power	4x original	4.929	5.271		x	x

Performance Test of Tracer Gas Detectors

Jan 8 2021

Detector 91
Detector 92

Goal: show Detectors trend uniformly with changing levels of tracer gas (sulfur hexafluoride).

Stack tests measure variability of tracer media across cross-section of duct.

Time	Fan Status	SF6 gas	Detector 91	Detector 92			
15:44:30	increase fan speed	4x original				txn	txn
15:45:00	80% power	4x original	2.830	3.023		txn	txn
15:45:30	80% power	4x original	2.939	3.156		3.013	3.234
15:46:00	80% power	4x original	3.188	3.386		x	x
15:47:00	80% power	4x original	3.056	3.267		x	x
15:48:00	80% power	4x original	3.283	3.483		x	x
15:48:30	80% power	4x original	2.844	3.077		x	x
15:49:00	80% power	4x original	2.706	2.936		x	x
15:49:30	80% power	4x original	3.074	3.333		x	x
					Average for each setting		
New approach; keep regulator coarse adjust constant; fine adjust set to 2 psi; use fine adjust to change gas level					PSI	Det.91	Det.92
15:53:00	80% power	2	3.027	3.240	2	2.989	3.208
15:53:30	80% power	2	2.848	3.091	x	x	x
15:54:00	80% power	2	2.985	3.220	x	x	x
15:54:30	80% power	2	3.011	3.224	x	x	x
15:55:00	80% power	2	3.234	3.419	x	x	x
15:55:30	80% power	2	2.942	3.151	x	x	x
15:56:00	80% power	2	2.878	3.109	x	x	x
15:56:30	80% power				x	txn	txn
15:57:00	80% power	2.5	3.117	3.373	2.5	3.164	3.387
15:57:30	80% power	2.5	3.217	3.432	x	x	x
15:58:00	80% power	2.5	3.207	3.448	x	x	x
15:58:30	80% power	2.5	3.066	3.274	x	x	x
15:59:00	80% power	2.5	3.509	3.660	x	x	x
15:59:30	80% power	2.5	2.740	2.978	x	x	x
16:00:00	80% power	2.5	3.007	3.226	x	x	x
16:00:30	80% power	2.5	3.448	3.703	x	x	x
16:01:00	80% power				x	txn	txn
16:01:30	80% power	3	3.989	4.240	3	3.466	3.728
16:02:00	80% power	3	3.794	4.104	x	x	x
16:02:30	80% power	3	3.326	3.600	x	x	x
16:03:00	80% power	3	3.115	3.371	x	x	x

Performance Test of Tracer Gas Detectors

Jan 8 2021

Detector 91
Detector 92

Goal: show Detectors trend uniformly with changing levels of tracer gas (sulfur hexafluoride).

Stack tests measure variability of tracer media across cross-section of duct.

Time	Fan Status	SF6 gas	Detector 91	Detector 92			
16:03:30	80% power	3	3.405	3.679	x	x	x
16:04:00	80% power	3	3.164	3.373	x	x	x
16:04:30	80% power				x	x	x
16:05:00	80% power	4	4.282	4.527	4	4.019	4.306
16:05:30	80% power	4	3.900	4.123	x	x	x
16:06:00	80% power	4	4.315	4.678	x	x	x
16:06:30	80% power	4	4.288	4.640	x	x	x
16:07:00	80% power	4	3.735	4.016	x	x	x
16:07:30	80% power	4	4.001	4.253	x	x	x
16:08:00	80% power	4	3.615	3.902	x	x	x
16:08:30	80% power				x	txn	txn
16:09:00	80% power	5	4.817	5.193	5	4.891	5.200
16:09:30	80% power	5	5.335	5.617	x	x	x
16:10:00	80% power	5	4.722	5.111	x	x	x
16:10:30	80% power	5	4.957	5.245	x	x	x
16:11:00	80% power	5	4.614	4.979	x	x	x
16:11:30	80% power	5	4.623	4.845	x	x	x
16:12:00	80% power	5	5.381	5.606	x	x	x
16:12:30	80% power	5	4.681	5.005	x	x	x
16:13:00	80% power				x	txn	txn
16:13:30	80% power	6	5.539	5.840	6	5.636	5.990
16:14:00	80% power	6	5.614	5.940	x	x	x
16:14:30	80% power	6	5.387	5.693	x	x	x
16:15:00	80% power	6	5.832	6.236	x	x	x
16:15:30	80% power	6	6.085	6.404	x	x	x
16:16:00	80% power	6	5.350	5.692	x	x	x
16:16:30	80% power	6	5.637	6.030	x	x	x
16:17:00	80% power	6	5.647	6.087	x	x	x
16:17:30	80% power				x	txn	txn
16:18:00	80% power	7	5.590	6.141	7	5.859	6.284
16:18:30	80% power	7	5.456	5.903	x	x	x
16:19:00	80% power	7	6.730	7.304	x	x	x
16:19:30	80% power	7	5.995	6.400	x	x	x

Performance Test of Tracer Gas Detectors

Jan 8 2021

Detector 91
Detector 92

Goal: show Detectors trend uniformly with changing levels of tracer gas (sulfur hexafluoride).

Stack tests measure variability of tracer media across cross-section of duct.

Time	Fan Status	SF6 gas	Detector 91	Detector 92			
16:20:00	80% power	7	5.752	6.113	x	x	x
16:20:30	80% power	7	5.705	6.036	x	x	x
16:21:00	80% power	7	5.865	6.218	x	x	x
16:21:30	80% power	7	5.778	6.157	x	x	x
16:22:00	80% power				x	txn	txn
16:22:30	80% power	8	6.587	7.001	8	6.549	6.981
16:23:00	80% power	8	6.744	7.198	x	x	x
16:23:30	80% power	8	6.583	7.053	x	x	x
16:24:00	80% power	8	6.140	6.530	x	x	x
16:24:30	80% power	8	6.691	7.121	x	x	x
16:25:00	80% power				x	txn	txn
16:25:30	80% power	5	4.961	5.322	5	4.791	5.184
16:26:00	80% power	5	5.320	5.775	x	x	x
16:26:30	80% power	5	4.947	5.365	x	x	x
16:27:00	80% power	5	4.748	5.182	x	x	x
16:27:30	80% power	5	4.498	4.843	x	x	x
16:28:00	80% power	5	4.770	5.116	x	x	x
16:28:30	80% power	5	4.290	4.662	x	x	x
16:29:00	80% power	5	4.792	5.208	x	x	x
					New test; 50% fan power		
	decrease fan power	stay 5 psi			PSI	Det.91	Det.92
16:31:00	50% power	5	7.123	7.796	5	7.172	7.886
16:31:30	50% power	5	6.526	7.134	x	x	x
16:32:00	50% power	5	7.368	8.059	x	x	x
16:32:30	50% power	5	7.149	8.012	x	x	x
16:33:00	50% power	5	6.851	7.467	x	x	x
16:33:30	50% power	5	7.429	8.196	x	x	x
16:34:00	50% power	5	7.761	8.540	x	x	x
16:34:30	50% power				x	txn	txn
16:35:00	50% power	3	5.123	5.534	3	5.316	5.730
16:35:30	50% power	3	5.615	6.060	x	x	x
16:36:00	50% power	3	5.424	5.814	x	x	x
16:36:30	50% power	3	5.223	5.659	x	x	x

Performance Test of Tracer Gas Detectors

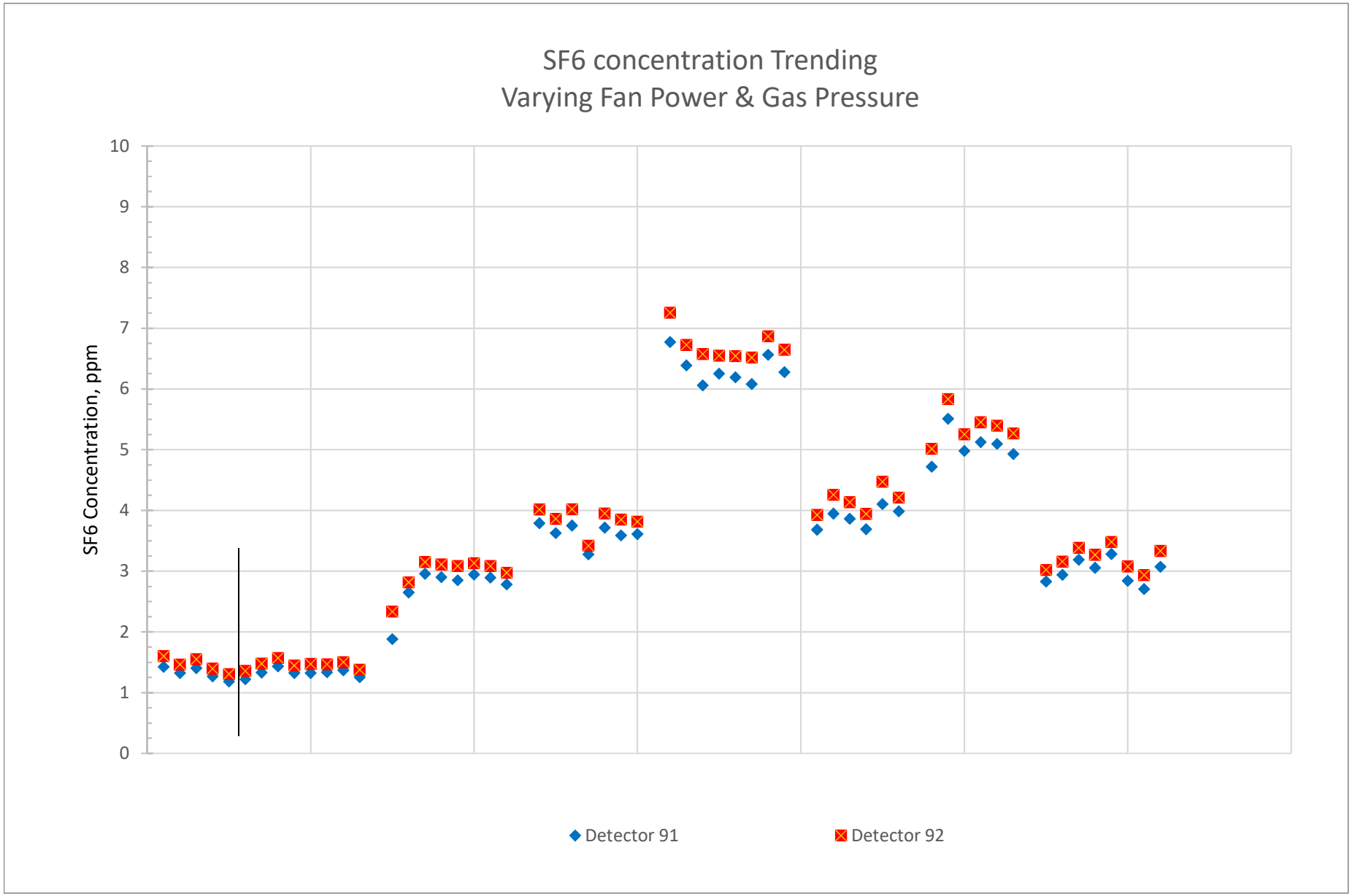
Jan 8 2021

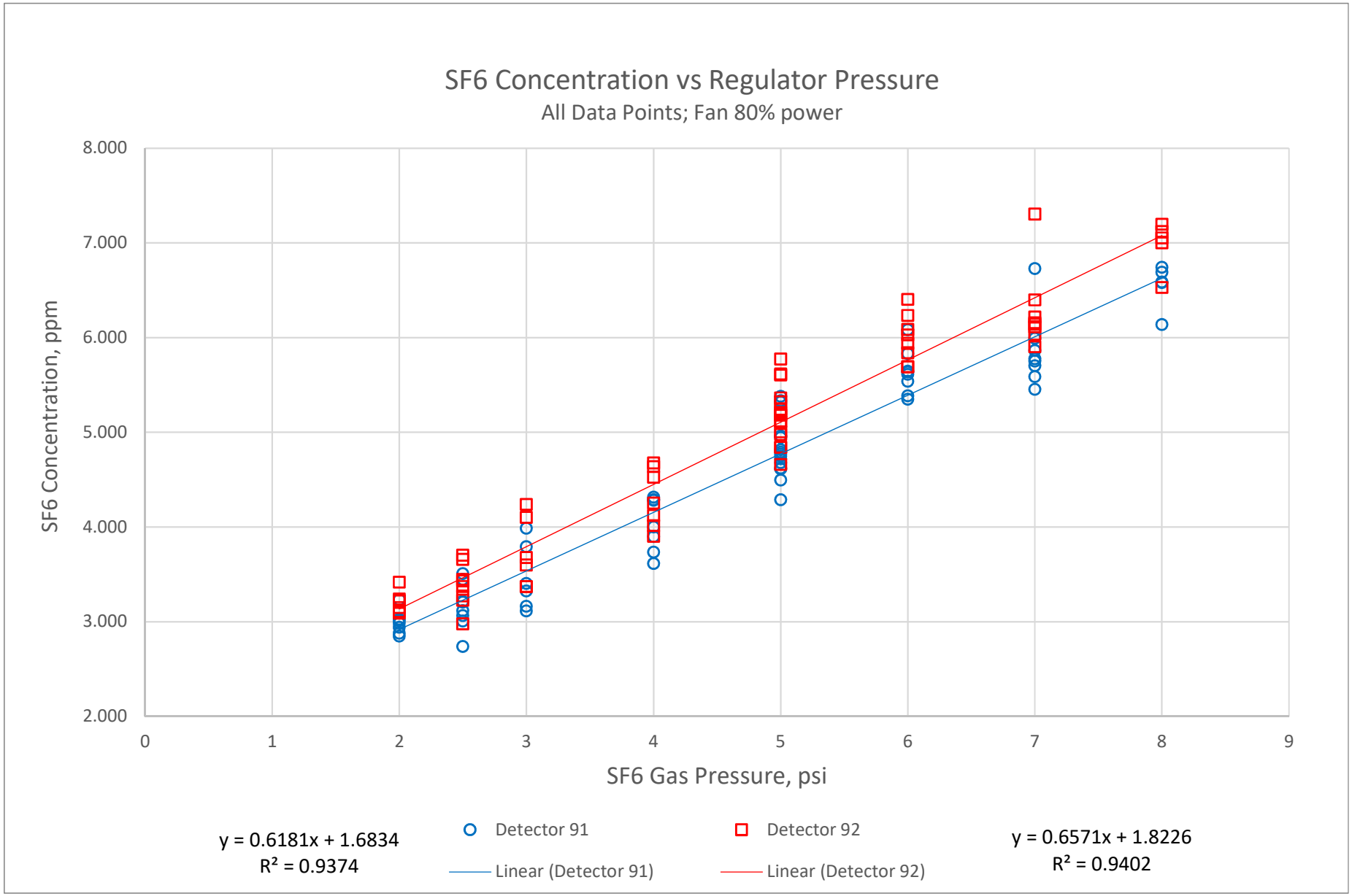
Detector 91
Detector 92

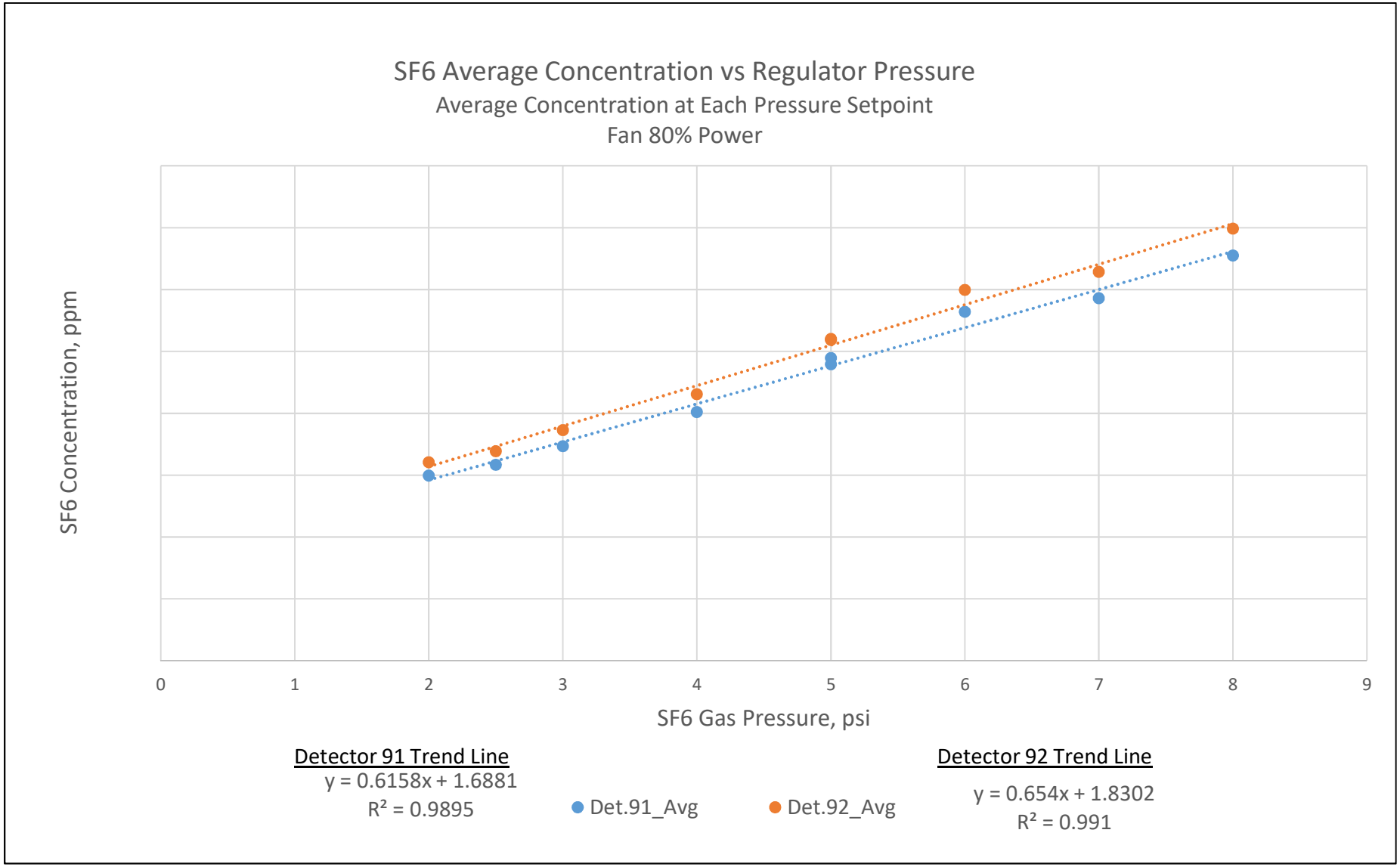
Goal: show Detectors trend uniformly with changing levels of tracer gas (sulfur hexafluoride).

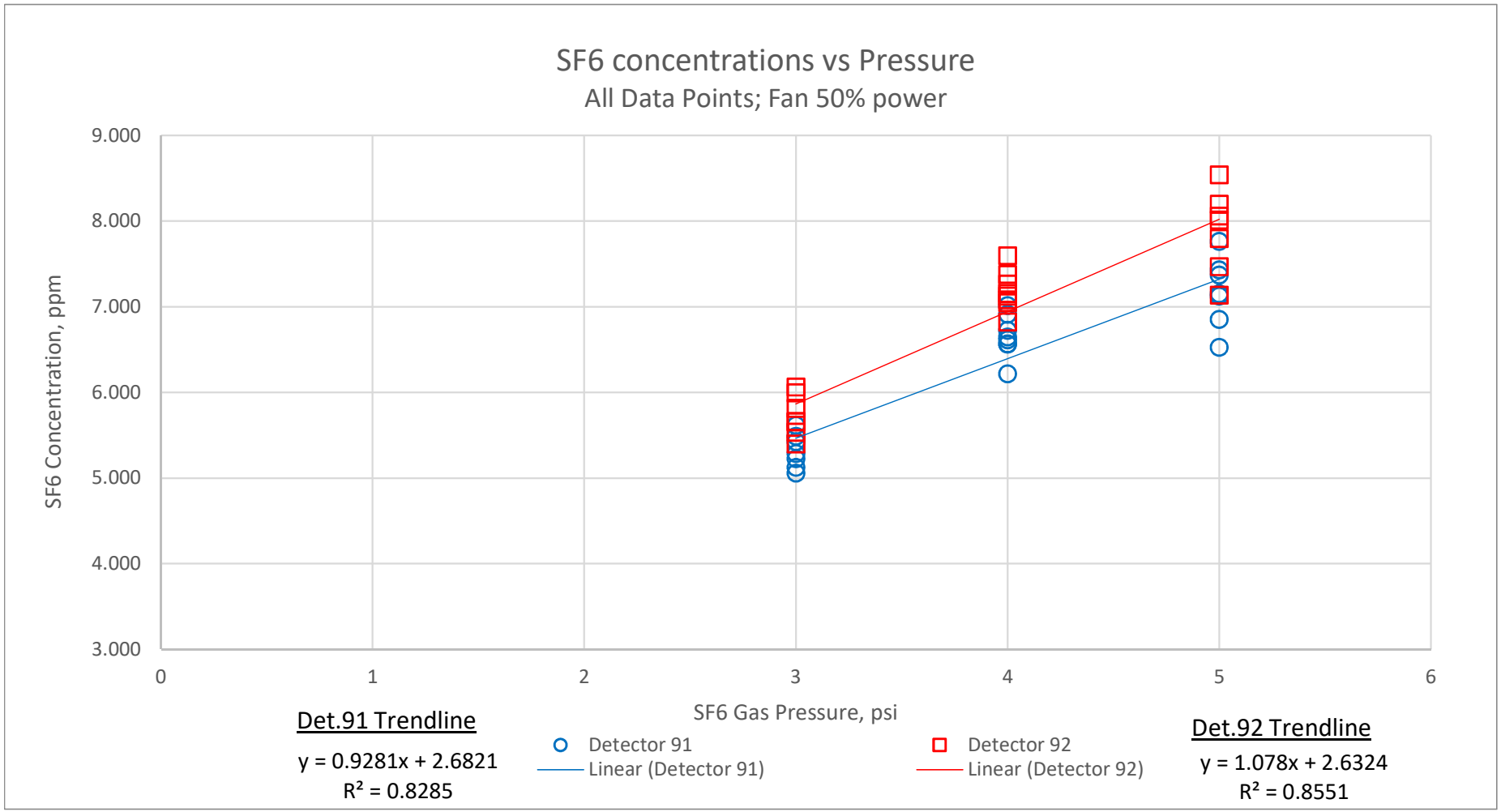
Stack tests measure variability of tracer media across cross-section of duct.

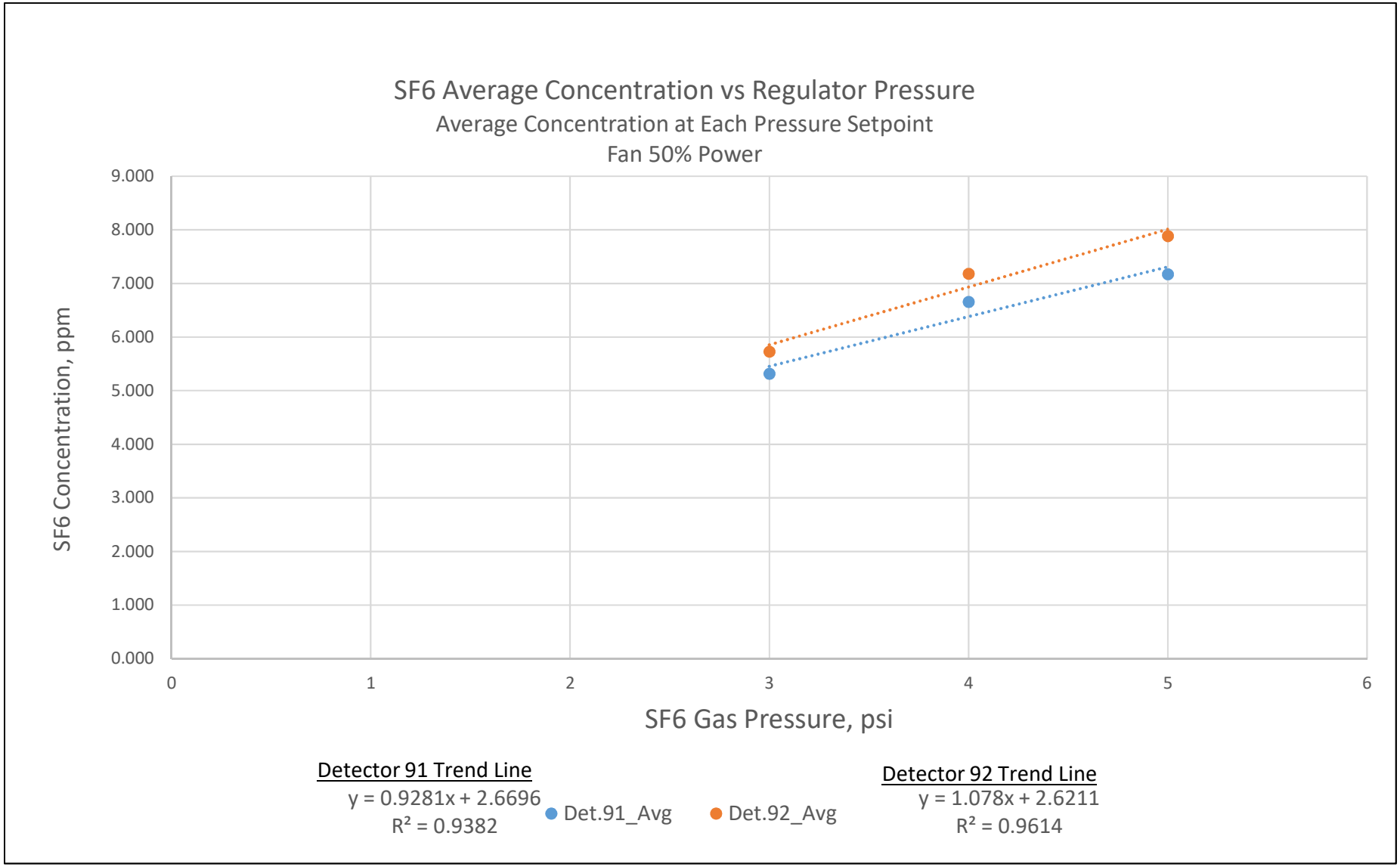
Time	Fan Status	SF6 gas	Detector 91	Detector 92			
16:37:00	50% power	3	5.058	5.397	x	x	x
16:37:30	50% power	3	5.284	5.655	x	x	x
16:38:00	50% power	3	5.487	5.993	x	x	x
	50% power				x	txn	txn
16:39:30	50% power	4	6.614	7.081	4	6.657	7.183
16:40:00	50% power	4	6.913	7.376	x	x	x
16:40:30	50% power	4	6.216	6.820	x	x	x
16:41:00	50% power	4	7.013	7.594	x	x	x
16:41:30	50% power	4	6.565	7.045	x	x	x
16:42:00	50% power	4	6.647	7.155	x	x	x
16:42:30	50% power	4	6.724	7.266	x	x	x
16:43:00	50% power	4	6.563	7.124	x	x	x
	50% power						
16:44:30	50% power	off	0.032	0.147			
	50% power						
16:51:00	50% power	off	-0.070	0.041			


SF6 concentration Trending
Varying Fan Power & Gas Pressure
SF6 Concentration, ppm
10
9
8
7
6
5
4
3
2
1
0
Detector 91
Detector 92


SF6 Concentration vs Regulator Pressure
All Data Points; Fan 80% power
SF6 Concentration, ppm
8.000
7.000
6.000
5.000
4.000
3.000
2.000
0
1
2
3
4
5
6
7
8
9
SF6 Gas Pressure, psi
y = 0.6181x + 1.6834
R² = 0.9374
Detector 91
Detector 92
Linear (Detector 91)
Linear (Detector 92)
y = 0.6571x + 1.8226
R² = 0.9402


SF6 Average Concentration vs Regulator Pressure
Average Concentration at Each Pressure Setpoint
Fan 80% Power
SF6 Concentration, ppm
0
1
2
3
4
5
6
7
8
9
SF6 Gas Pressure, psi
Detector 91 Trend Line
y = 0.6158x + 1.6881
R² = 0.9895
Det.91_Avg
Det.92_Avg
Detector 92 Trend Line
y = 0.654x + 1.8302
R² = 0.991


SF6 concentrations vs Pressure
All Data Points; Fan 50% power
SF6 Concentration, ppm
9.000
8.000
7.000
6.000
5.000
4.000
3.000
0
1
2
3
4
5
6
SF6 Gas Pressure, psi
Det.91 Trendline
y = 0.9281x + 2.6821
R² = 0.8285
Detector 91
Linear (Detector 91)
Detector 92
Linear (Detector 92)
Det.92 Trendline
y = 1.078x + 2.6324
R² = 0.8551


SF6 Average Concentration vs Regulator Pressure
Average Concentration at Each Pressure Setpoint
Fan 50% Power
SF6 Concentration, ppm
9.000
8.000
7.000
6.000
5.000
4.000
3.000
2.000
1.000
0.000
0
1
2
3
4
5
6
SF6 Gas Pressure, psi
Detector 91 Trend Line
y = 0.9281x + 2.6696
R² = 0.9382
Det.91_Avg
Det.92_Avg
Detector 92 Trend Line
y = 1.078x + 2.6211
R² = 0.9614

Attachment 2

Aerosol Particle Counter Tests - Data, Calculations, & Graphs

Functional Test of aerosol particle counter — Jan.2021

Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be cal'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.

Stack tests measure variability of aerosol across cross-section of duct.

Status	Det02 - 5 um	Det02 - 10 um	Det03 - 5 um	Det03 - 10 um
Zero Check 1	0	0	0	0
Zero Check 2	0	0	0	0
no aerosol; fan off	115	2	242	5
no aerosol; fan off	91	1	236	9
no aerosol; fan off	93	5	243	3
no aerosol; fan off	104	1	261	3
no aerosol; fan 35%	543	85	1154	87
no aerosol; fan 35%	138	4	318	7
aerosol on; fan 35%	190158	1730	490946	4499
aerosol on; fan 35%	304611	2996	783820	7415
aerosol on; fan 35%	267628	2763	695608	6511
aerosol on; fan 35%	257182	2633	668609	6159
aerosol on; fan 35%	242544	2514	638430	5722
aerosol on; fan 70%	156408	1642	429706	4253
aerosol on; fan 70%	124128	1277	329534	3260
aerosol on; fan 70%	129689	1303	352110	3401
aerosol on; fan 70%	128736	1340	341994	3256
aerosol on; fan 70%	134041	1326	359572	3549
aerosol on; fan 70%	129409	1265	353136	3355
aerosol on; fan 25%	221602	2166	569850	4982
aerosol on; fan 25%		4170	1113374	9657
aerosol on; fan 25%	404385	3860	1049923	8985
aerosol on; fan 25%	405378	3932	1051699	8946
aerosol on; fan 25%	421807	4030	1108185	9429
fan to 80%				
aerosol on; fan 80%	106675	1065	297665	2854
aerosol on; fan 80%	108567	1111	301434	2813
aerosol on; fan 80%	127805	1177	360632	3313
aerosol on; fan 80%	153364	1520	418783	3968
fan to 50%	170025	1664	459381	3961
aerosol on; fan 50%	190336	1949	529250	4629
aerosol on; fan 50%	191214	1935	531832	4503
aerosol on; fan 50%	204524	2034	559486	4869
aerosol on; fan 50%	216903	2159	553093	5072
aerosol on; fan 50%	204385	2141	547391	4928
aerosol shut off; fan 50%				
aerosol shut off; fan 50%	10574	96	30743	181
aerosol shut off; fan 50%	431	4	1288	8
missed reading during cleanup				
aerosol shut off; fan 50%	197	1	619	6
aerosol shut off; fan 50%	277	17	677	14
fan off; aerosol off	294	2	907	11
fan off; aerosol off	257	1	833	3

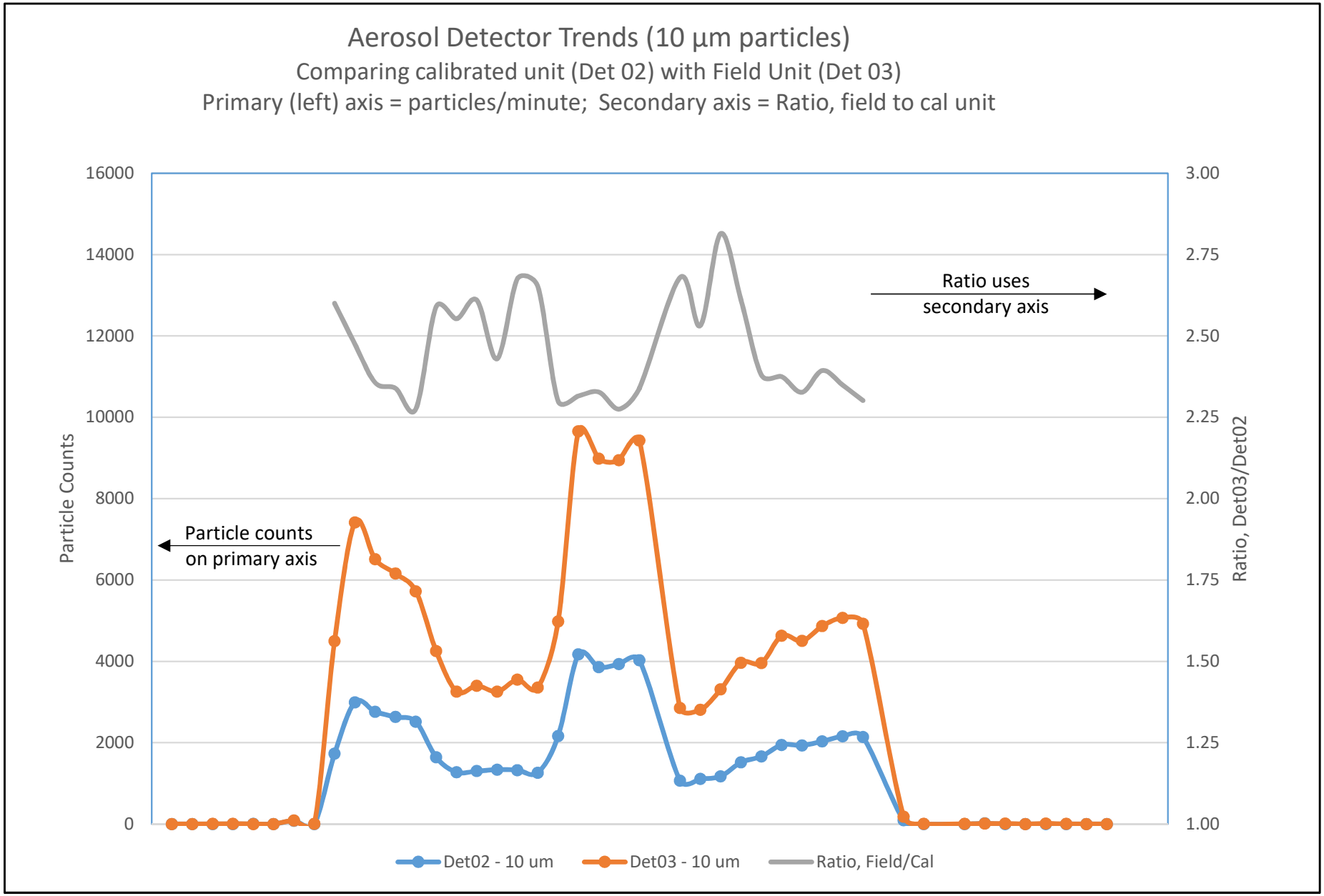
Functional Test of aerosol particle counter — Jan.2021

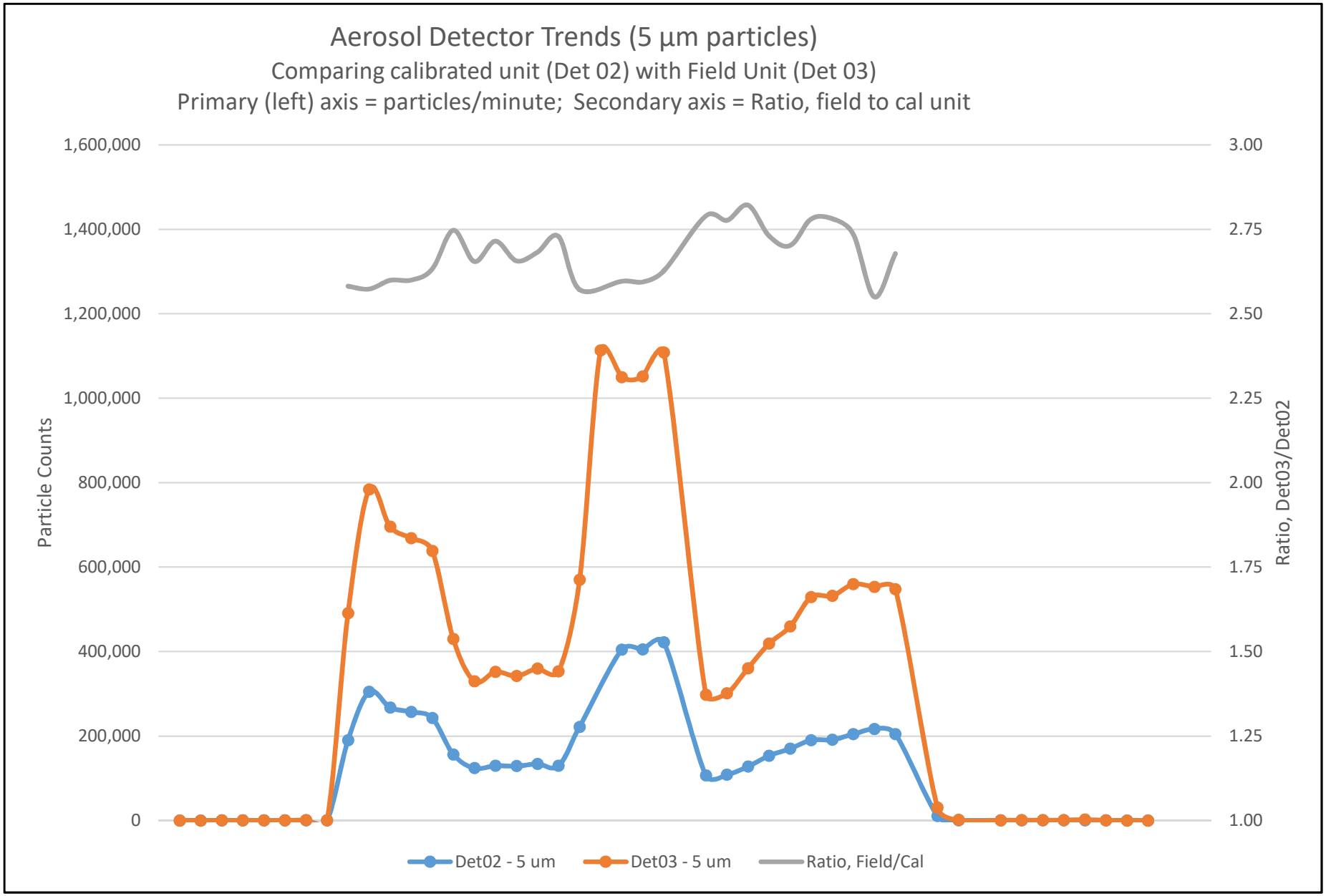
Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be cal'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.

Stack tests measure variability of aerosol across cross-section of duct.

Status	Det02 - 5 um	Det02 - 10 um	Det03 - 5 um	Det03 - 10 um
fan off; aerosol off	593	2	1899	13
fan off; aerosol off	103	3	286	5
Zero Check	0	0	0	0
Zero Check	0	0	0	0
Zero Check	0	0	0	0
Zero Check	0	0	0	0


Aerosol Detector Trends (10 µm particles)
Comparing calibrated unit (Det 02) with Field Unit (Det 03)
Primary (left) axis = particles/minute; Secondary axis = Ratio, field to cal unit
Particle Counts
Ratio, Det03/Det02
16000
14000
12000
10000
8000
6000
4000
2000
0
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
Ratio uses
secondary axis
Particle counts
on primary axis
Det02 - 10 um
Det03 - 10 um
Ratio, Field/Cal


Aerosol Detector Trends (5 µm particles)
Comparing calibrated unit (Det 02) with Field Unit (Det 03)
Primary (left) axis = particles/minute; Secondary axis = Ratio, field to cal unit
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Particle Counts
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
1.00
Ratio, Det03/Det02
Det02 - 5 um
Det03 - 5 um
Ratio, Field/Cal

Functional Test of aerosol particle counter

		Five Micron Size Bin		Ten Micron Size Bin
Detector 02 - calibrated unit	**Goal**: show Detector 3 (field unit, non-calibrated)	2.676	Average Ratio of (Det2/Det3)	2.457
Detector 03 - Field Work unit	varies similarly to the calibrated unit Detector 2.	0.08	Std Dev of Ratio, (Det2/Det3)	0.15
Det3 cannot be calibrated after use in rad area	*Stack tests measure variability of aerosol across cross-section of duct.*	**3.0%**	Coef. of Variation (StdDev/Avg)	**6.3%**

Particle counts in one-minute interval; looking @ 5 micron and 10 micron bins.

test run / fan status	Aerosol Source	Plot Point	Det02 - 5 um	Det03 - 5 um	Ratio, Field/Cal	Det02 - 10 um	Det03 - 10 um	Ratio, Field/Cal
Zero Check 1	ZeroFilter	1	*0*	*0*		*0*	*0*	
Zero Check 2	ZeroFilter	2	*0*	*0*		*0*	*0*	
no aerosol; fan off	none	3	*115*	*242*	*2.10*	*2*	*5*	*2.50*
no aerosol; fan off	none	4	*91*	*236*	*2.59*	*1*	*9*	*9.00*
no aerosol; fan off	none	5	*93*	*243*	*2.61*	*5*	*3*	*0.60*
no aerosol; fan off	none	6	*104*	*261*	*2.51*	*1*	*3*	*3.00*
no aerosol; fan 35%	none	7	*543*	*1,154*	*2.13*	*85*	*87*	*1.02*
no aerosol; fan 35%	none	8	*138*	*318*	*2.30*	*4*	*7*	*1.75*
aerosol on; fan 35%	begin inject	9	190,158	490,946	2.58	1,730	4,499	2.60
aerosol on; fan 35%	oil inject	10	304,611	783,820	2.57	2,996	7,415	2.47
aerosol on; fan 35%	oil inject	11	267,628	695,608	2.60	2,763	6,511	2.36
aerosol on; fan 35%	oil inject	12	257,182	668,609	2.60	2,633	6,159	2.34
aerosol on; fan 35%	oil inject	13	242,544	638,430	2.63	2,514	5,722	2.28
aerosol on; fan 70%	oil inject	14	156,408	429,706	2.75	1,642	4,253	2.59
aerosol on; fan 70%	oil inject	15	124,128	329,534	2.65	1,277	3,260	2.55
aerosol on; fan 70%	oil inject	16	129,689	352,110	2.72	1,303	3,401	2.61
aerosol on; fan 70%	oil inject	17	128,736	341,994	2.66	1,340	3,256	2.43
aerosol on; fan 70%	oil inject	18	134,041	359,572	2.68	1,326	3,549	2.68
aerosol on; fan 70%	oil inject	19	129,409	353,136	2.73	1,265	3,355	2.65
aerosol on; fan 25%	oil inject	20	221,602	569,850	2.57	2,166	4,982	2.30
aerosol on; fan 25%	oil inject	21	fail to record Det2	1,113,374		4,170	9,657	2.32
aerosol on; fan 25%	oil inject	22	404,385	1,049,923	2.60	3,860	8,985	2.33
aerosol on; fan 25%	oil inject	23	405,378	1,051,699	2.59	3,932	8,946	2.28
aerosol on; fan 25%	oil inject	24	421,807	1,108,185	2.63	4,030	9,429	2.34
fan to 80%	oil inject	25						
aerosol on; fan 80%	oil inject	26	106,675	297,665	2.79	1,065	2,854	2.68
aerosol on; fan 80%	oil inject	27	108,567	301,434	2.78	1,111	2,813	2.53
aerosol on; fan 80%	oil inject	28	127,805	360,632	2.82	1,177	3,313	2.81
aerosol on; fan 80%	oil inject	29	153,364	418,783	2.73	1,520	3,968	2.61

test run / fan status	Aerosol Source	Plot Point	Det02 - 5 um	Det03 - 5 um	Ratio, Field/Cal	Det02 - 10 um	Det03 - 10 um	Ratio, Field/Cal
fan to 50%	oil inject	30	170,025	459,381	2.70	1,664	3,961	2.38
aerosol on; fan 50%	oil inject	31	190,336	529,250	2.78	1,949	4,629	2.38
aerosol on; fan 50%	oil inject	32	191,214	531,832	2.78	1,935	4,503	2.33
aerosol on; fan 50%	oil inject	33	204,524	559,486	2.74	2,034	4,869	2.39
aerosol on; fan 50%	oil inject	34	216,903	553,093	2.55	2,159	5,072	2.35
aerosol on; fan 50%	oil inject	35	204,385	547,391	2.68	2,141	4,928	2.30
aerosol shut off; fan 50%	stop inject	36						
aerosol shut off; fan 50%	none	37	*10,574*	*30,743*	*2.91*	96	181	*1.89*
aerosol shut off; fan 50%	none	38	*431*	*1,288*	*2.99*	*4*	*8*	*2.00*
missed reading during cleanup	none	39						
aerosol shut off; fan 50%	none	40	*197*	*619*	*3.14*	*1*	*6*	*6.00*
aerosol shut off; fan 50%	none	41	*277*	*677*	*2.44*	*17*	*14*	*0.82*
fan off; aerosol off	none	42	*294*	*907*	*3.09*	*2*	*11*	*5.50*
fan off; aerosol off	none	43	*257*	*833*	*3.24*	*1*	*3*	*3.00*
fan off; aerosol off	none	44	*593*	*1,899*	*3.20*	*2*	*13*	*6.50*
fan off; aerosol off	none	45	*103*	*286*	*2.78*	*3*	*5*	*1.67*
Zero Check	ZeroFilter	46	0	0		*0*	*0*	
Zero Check	ZeroFilter	47+	0	0		*0*	*0*	

Attachment 3

Raw data sheets, all tests

Aero p1 of 2

Functional Test of aerosol particle counter

Jan.2021

Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be cal'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.

Stack tests measure variability of aerosol across cross-section of duct

1/8/2021

Status	02@5	02@10		03@5	03@10	
Zero Check 1	115	2		242	5	
Zero Check 2	91	1		236	9	
Bkgd 1 (hoses down)	93	5		243	3	
Bkgd Meas 2	104	1		261	3	
Bkgd Meas 3	543	85		1154	87	
Bkgd 4 (hoses up)	138	4		318	7	
Bkgd Meas 5	190158	1730	Sbg	490946	4499	
Bkgd Meas 6	304611	2996	1	783820	7415	
Fan at 50% Meas 1	267628	2763	2	695608	6571	
Fan at 50% Meas 2	257182	2633	3	668609	6159	
Fan at 50% Meas 3	242544	2574	4	638450	5722	
Fan at 50% Meas 4	156408	1642	TX	429796	4253	
Fan at 70% Meas 1	124128	1277	1	325534	3260	
Fan at 70% Meas 2	129689	1303	2	352110	3401	
Fan at 70% Meas 3	128736	1340	3	341994	3256	
Fan at 70% Meas 4	134041	1326	4	359572	3549	
Fan at 35% Meas 1	129409	1265	5	353136	3355	
Fan at 35% Meas 2	221602	2166	TX	569850	4982	
Fan at 35% Meas 3	423—	4170	1	1113374	9657	
Fan at 35% Meas 4	404385	3860	2	1049923	8985	
Fan at 60% Meas 1	405378	3932	3	1051699	8946	
Fan at 60% Meas 2	421807	4030	4	1108185	9429	
Fan at 60% Meas 3	?	?	TX	?	~4000	
Fan at 60% Meas 4	106675	1065	1	297665	2854	
Bkgd Meas 1	108567	1111	2	301434	2813	
Bkgd Meas 2	127805	1177	3	360362	3313	
Zero Check	153364	1520	4	418783	3968	

FAN 35
35
35
35
35
35 to 70
70
70
70
70
70
25
25
25
25
25
80
80
80
80

all zero checks

Bkgd no Aero

INSect

3313

Missed TX

360632

Aero p2 of 2

Functional Test of aerosol particle counter

Jan.2021

Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be cal'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.
Stack tests measure variability of aerosol across cross-section of duct.

1/8/2021 (p2)

Status	Det2 @ 5	@ 10		Det3 @ 5	@ 10	
Zero Check 1 to 50	170025	1664		459381	3961	Aero on
Zero Check 2 @ 50	190336	1949		529250	4629	
Bkgd 1 (hoses down) 50	191214	1935		~~513733~~	4503	531832
Bkgd Meas 2 50	204524	2034		559486	4869	559486
Bkgd Meas 3 50	216903	2159		583093	5072	
Bkgd 4 (hoses up) 50	204385	2141		547391	4928	
Bkgd Meas 5 50		aerosol off			missed	aerosol out Fan out
Bkgd Meas 6 50	10574	96	1	30743	181	
Fan at 50% Meas 1	431	4	2	1288	8	
Fan at 50% Meas 2		missed		cleaning up		
Fan at 50% Meas 3 50	197	1	3	619	6	
Fan at 50% Meas 4 50	271	17	4	677	14	walked past tunnel entry
Fan at 70% Meas 1 Fan off	294	2	TX	907	61	
Fan at 70% Meas 2	257	1		~~833~~	~~4~~ 3	
Fan at 70% Meas 3	~~5~~93	2		1849	13	
Fan at 70% Meas 4	103	3		286	5	
Fan at 35% Meas 1						
Fan at 35% Meas 2 Zero	0	0		0	0	
Fan at 35% Meas 3 Fan	0	0		0	0	
Fan at 35% Meas 4	↓			↓		
Fan at 60% Meas 1						
Fan at 60% Meas 2						
Fan at 60% Meas 3	0	0		0	0	
Fan at 60% Meas 4						
Bkgd Meas 1						
Bkgd Meas 2						
Zero Check						

SF_6 TRACER GAS

p1 of 4

Functional Test of ~~aerosol particle counter~~ SF_6 — Jan.2021

Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be call'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.
Stack tests measure variability of aerosol across cross-section of duct.

1/8/21

Status	# 91	92	1682	2334
Zero Check 1	-0.025	-0.044	INC GAS; Fan 60%	
Zero Check 2	-0.025	-0.042	2.650	2.815
Bkgd 1 (hoses down) 2:57	-0.027	-0.041	2.956	3,151
Bkgd Meas 2 2:58	-0.026	-0.040	2.902	3,112
Bkgd Meas 3	-0.027	-0.040	2.850	3,086
Bkgd 4 (hoses up) Fan ON	-0.025	-0.037	2,945	3,133
Bkgd Meas 5	-0.024	-0.039	2.893	3.084
Bkgd Meas 6 50 Gas OFF	-0.030	-0.040	2.783	2.976
Fan at 50% Meas 1	-0.030	-0.042	bump up Gas Fan 60%	
Fan at 50% Meas 2 Gas ON	SATURATED		3.790	4,014
Fan at 50% Meas 3 Fan 80%	Fan to 80, Gas off		3.628	3.862
Fan at 50% Meas 4	Rezeroed Both		3,750	4,022
Fan at 70% Meas 1	-0.074	+0.017	3,277	3.419
Fan at 70% Meas 2 316	-0.078	+0.010	3.718	3.952
Fan at 70% Meas 3 317	1.426 Gas ON	1,600 ?	3.587	3.850
Fan at 70% Meas 4 15:47:30	1.323	1.464	3.612	3.814
Fan at 35% Meas 1 15:18:00	1.403	1.550	Fan 30%	
Fan at 35% Meas 2 15:18:30	1.266	1.397	6.771	7.255
Fan at 35% Meas 3	1.181	1.307	6.384	6.725
Fan at 35% Meas 4	1.221	1.358	6.058	6.577
15:20:00 Fan at 60% Meas 1 Fan 60%	1.332	1.477	6.253	6.552
15:20:30 Fan at 60% Meas 2	1.436	1.570	6.190	6.541
Fan at 60% Meas 3	1.322	1.446	6.081	6.579
Fan at 60% Meas 4	1.325	1.474	6.562	6.867
15:22:00 Bkgd Meas 1	1.336	1.470	6.276	6.645
Bkgd Meas 2	1.368	1.501	FAN OFF	
15:23:00 Zero Check	1.253	1.377		

30 sec intervals

15:29:00
15:30:00
15:32:00
15:33:30
15:34:00
15:36:00
15:37:00
15:36:30

GAS p2 of 4

Functional Test of ~~aerosol particle counter~~ SFE

Jan.2021

Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be cal'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.
Stack tests measure variability of aerosol across cross-section of duct.

2-2.25

Status	#41	#92	Gas ~ 2.25 psi Fan 80%	
Zero Check 1 15:38:00	3,681	3,926	3,077	3,240 15:53:00
Zero Check 2 38:30	3,948	4,259	2,848	3,091 5330
Bkgd 1 (hoses down) 39	3,863	4,135	2,985	3,220
Bkgd Meas 2 39:30	3,692	3,945	3,011	3,224
Bkgd Meas 3 40:00	4,104	4,473	3,234	3,419
Bkgd 4 (hoses up) 40:30	3,988	4,214	2,942	3,157
Bkgd Meas 5 41:00	GAS turned UP		2,878	3,109
Bkgd Meas 6 15 41:30	4721	5013	2.5 psi Fan 80%	
Fan at 50% Meas 1 154200	5,511	5,833	3,117	3,373 155900
Fan at 50% Meas 2 42:30	4,979	5,253	3,217	3,432 58:30
Fan at 50% Meas 3	5,125	5,454	3,207	3,448
Fan at 50% Meas 4	5,094	5,393	3,066	3,274
Fan at 70% Meas 1	4,929	5,271	3,509	3,660 16:00:00
Fan at 70% Meas 2	FAN TO 80		2,740	2,978
Fan at 70% Meas 3 15:45:00	2,830	3,023	3,007	3,226
Fan at 70% Meas 4	2,939	3,156	3,448	3,703
Fan at 35% Meas 1 46:00	3,188	3,386	to 3 psi Fan 80	
Fan at 35% Meas 2 47:00	3,056	3,267	3,989	4,240 160250
Fan at 35% Meas 3 48:00	3,283	3,483	3,794	4,104 160300
Fan at 35% Meas 4 48:30	2,844	3,077	3,326	3,600
Fan at 60% Meas 1	2,706	2,936	3,115	3,371
Fan at 60% Meas 2	3,074	3,333	3,405	3,679 16:04:30
Fan at 60% Meas 3			3,164	3,373 16:05
Fan at 60% Meas 4	Try to get		4 psi	
Bkgd Meas 1	Stable gas		4,282	4,527 16:06:00
Bkgd Meas 2	@ visible.		3,900	4,123 16:06:30
Zero Check	psi		4,315	4,678 16:07:00

FAN 45:00

Functional Test of ~~aerosol particle counter~~ SFC — Jan.2021

Detector 02 - Calibrated
Detector 03 - Field Unit
Det3 can't be cal'd after use in rad area

Goal: show Detector 3 (field unit, non-calibrated) varies similarly to the calibrated unit Detector 2.
Stock tests measure variability of aerosol across cross-section of duct.

Status	#91	92	#91	#92	
Zero Check 1 16:07:30	4.288	4.640	5.752	6.113	16:21
Zero Check 2	3.735	4.016	5.705	6.036	
Bkgd 1 (hoses down) 08:30	4.001	4.253	5.865	6.218	16:22
Bkgd Meas 2 09:00	3.615	3.902	5.778	6.157	
Bkgd Meas 3	Gas to 5 psi		—3 psi—		
Bkgd 4 (hoses up) 16:10:00	4.817	5.193	6.587	7.001	16:23:30
Bkgd Meas 5	5.335	5.617	6.744	7.198	
Bkgd Meas 6 16:11:00	4.722	5.111	6.583	7.053	
Fan at 50% Meas 1	4.957	5.245	6.140	6.530	16:25:00
Fan at 50% Meas 2 12	4.614	4.979	6.691	7.121	
Fan at 50% Meas 3	4.623	4.845	to 5 psi	Fan	80%
Fan at 50% Meas 4 13	5.381	5.606	4.961	5.322	16:26:30
Fan at 70% Meas 1	4.691	5.005	5.320	5.775	16:27:00
Fan at 70% Meas 2	gas to 6 ps		4.947	5.360	
Fan at 70% Meas 3 16:13:30	5.534	5.840	4.748	5.182	16:28:00
Fan at 70% Meas 4 16:14:00	5.644	5.940	4.498	4.843	
Fan at 35% Meas 1	5.387	6.683	4.170	5.116	16:29:00
Fan at 35% Meas 2	5.832	6.236	4.290	4.662	
Fan at 35% Meas 3	6.085	6.404	4.792	5.208	
Fan at 35% Meas 4	5.390	5.692	5 psi	50% Fan	
Fan at 60% Meas 1 16:17:30	5.637	6.030	7.123	7.796	16:31:00
Fan at 60% Meas 2 16:18:00	5.647	6.087	6.526	7.134	
Fan at 60% Meas 3	to 7 ps		7.368	8.059	
Fan at 60% Meas 4 16:19:00	5.540	6.141	7.149	8.012	
Bkgd Meas 1	5.456	5.903 903	6.851	7.467	16:33:00
Bkgd Meas 2	6.730	7.304	7.429	8.196	
Zero Check 16:20:30	5.995	6.400	7.761	8.540	

80%
7psi Fading
4psi Fan 80%
5.590

	q1	q2	
3psi Fan 80%	5.123	5.534	16:35:00
	5.615	6.060	35 30
	5.424	5.814	
	5.223	5.659	
	5.058	5.397	16.37.00
	5.284	5.655	3730
	5.487	5993	3800
to 4psi 50% Fan			
	6.614	7.081	16:39:30
	6.913	7.376	16.40.00
	6.216	6.820	
	7.013	7.599	16:41:00
	6.565	7.045	16:41:30
	6.647	7.155	42:00
	6.724	7.266	
	6.563	7.124	16:43:00

Gas off + vent regulator Fan 50%

0.032 0.147 16:44:30

-0.070 0.041 16:57 OK

5 ft

4 ft